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APPLICATION NUMBER: *60/369,853*
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RELATED PCT APPLICATION NUMBER: *PCT/US03/10354*

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COMMISSIONER OF PATENTS AND TRADEMARKS

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April 5, 2002

Commissioner of Patents and Trademarks
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DELIVERED BY HAND

Dear Sir:

Please file the attached specification as a new **provisional** patent application:

Title:	**LIQUID-ASSISTED CRYOGENIC CLEANING**
Attorney's docket no.:	**PAT 51858P-2**
Fees:	**Please charge to the Borden Ladner Gervais LLP deposit account no. 501593 in the amount of $160** to cover the **large** entity filing fee. Any deficiency or overpayment should also be charged or credited to this deposit account. **An extra copy of this page is attached.**
Entitled to small entity fees?	No
No. of pages in specification:	Three (3)
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We look forward to confirmation of filing in due course.

Yours very truly,

Borden Ladner Gervais LLP

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IP-KIT-1/3174.1

LIQUID-ASSISTED CRYOGENIC CLEANING

BACKGROUND OF THE INVENTION

Field of the Invention

The invention proposes to use a liquid either simultaneously or sequentially with CO_2 snow cleaning to aid in removal of foreign materials (FM), e.g. particles and other contaminants, from semiconductor surfaces and other surfaces involved in precision cleaning.

It has been well established that for the defect-free manufacturing of integrated circuits, the minimum particle size that is considered to be a killer defect is 1/10th of the feature size (the gate width in a complimentary metal oxide semiconductor based device). Currently the semiconductor manufacturing industry is at 0.115 um technology node which implies that the killer particle is larger than 0.0115 um. Such small particles are difficult to remove since the ratio of the force of adhesion to removal increases for smaller particles. For submicron particles, the primary force of adhesion of particles to surfaces is the Van der Waals force which depends on the size of the particle, the distance of particle to substrate surface and the Hamaker constant. The Van der Waals force for a spherical particle on a flat substrate is given as in eqn. 1.

$$F_{Ad} = \frac{A_{132}\, d_p}{12 Z_0^2} \qquad (1)$$

where;

A_{132} is the Hamaker constant of the system composed of the particle, the surface, and the intervening medium.

d_p is the particle diameter

Z_0 is the distance of the particle from the surface.

The Hamaker constant A_{132} is given as in (2)

$$A_{132} = A_{12} + A_{33} - A_{13} - A_{23} \qquad (2)$$

Where $A_{ij} = (A_{ii} * A_{jj})^{1/2}$ and A_{ii} is the Hamaker constant of material i.

The Hamaker constant is theoretically calculated using either the Lifshitz or the London models. The Hamaker constant for particles and surfaces used in integrated circuit manufacturing processes is given in literature [1, 2] and has been seen to be less when the intervening medium is liquid as compared to air. The Van der Waals force being directly proportional to the Hamaker constant, therefore gets reduced when there is a liquid layer between the particle and the surface. Figure 1 shows a schematic of the post via etch wafer with the FM on the surface and inside the structure.

Prior Art

The prior art involves the use of CO_2 or Argon cryogenic spray for removing FM from surfaces (Aerosol Surface Processing, Rose et. al., Pat#5,931,721; Substrate Cleaning Method and Apparatus, Aoki, Pat. #6,036,581; Photoresist and redeposition removal using carbon dioxide jet spray, Bowers, Pat. #5,853,962; Aerosol Surface Processing, Rose et. al., Pat. #6,203,406; High Dispersion Carbon Dioxide Snow Apparatus, Zito, Pat. # 5,775,127). In all of the above prior arts, the FM are removed by physical force involving momentum transfer to the contaminants. Since there is no chemical component to the cleaning mechanism, this process is ineffective for removing small submicron particles and complex polymeric residues as generated by dielectric etch process. The prior art entitled Aerosol Substrate Cleaner, Fishkin et. al., Pat. #6,332,470 talks about using vapor only or in conjunction with high pressure liquid droplet for cleaning semiconductor substrate. Unfortunately, the liquid impact does not have sufficient momentum transfer capability as the solid CO_2 and will therefore not be as effective in removing the small particles for which the ratio of force of adhesion to removal increases. Residue Removal by Supercritical Fluids, McCullough, et. al., Pat. #5,908,510 talks of an idea of using cryogenic aerosol in conjunction with supercritical fluid or liquid CO_2. Since CO_2 is a non-polar molecule the solvation capability of polar FM is significantly reduced. Also since the liquid or supercritical CO_2 formation requires high pressure (greater than 75 psi for liquid and 1080 psi for supercritical), the equipment becomes expensive.

SUMMARY OF THE INVENTION

The invention uses a liquid such as, but not limited to, ethanol and acetone mixture to reduce the Van der Waals force of adhesion (75% reduction for a silica particle on bare Si wafer when the intervening medium between particle and surface is ethanol-acetone mixture as compared to air).

The liquid spray on the surface will facilitate the removal of FM with CO_2 snow cleaning where the removal mechanism will be physical in nature.

DETAILED DESCRIPTION

The invention proposes to utilize the reduction of Van der Waals force of adhesion by the introduction of liquid film on the wafer surface to aid in particle removal by the physical action of the CO_2 snow spray. In wet cleaning, a similar approach is used where the liquid medium reduces the Van der Waals force which helps the physical brush cleaning process to remove the contaminants.

One embodiment of this practice is spraying the liquid from a nozzle while spinning the wafer on a chuck to form a thin layer of liquid film on the wafer surface. Following the liquid spray, the CO_2 snow spray could then be applied over the wafer surface for particle removal. Alternatively the liquid could be applied through a second nozzle by atomization or by condensation of a vapor onto the surface of the substrate.

[1]. Particle Control for Semiconductor Manufacturing, Ed. R. P. Donovan, Marcel Dekker Inc., NY, 1990.

[2]. Handbook of Semiconductor Wafer Cleaning Technology, Ed. Werner Kern, Noyes Publications, NJ, 1993.

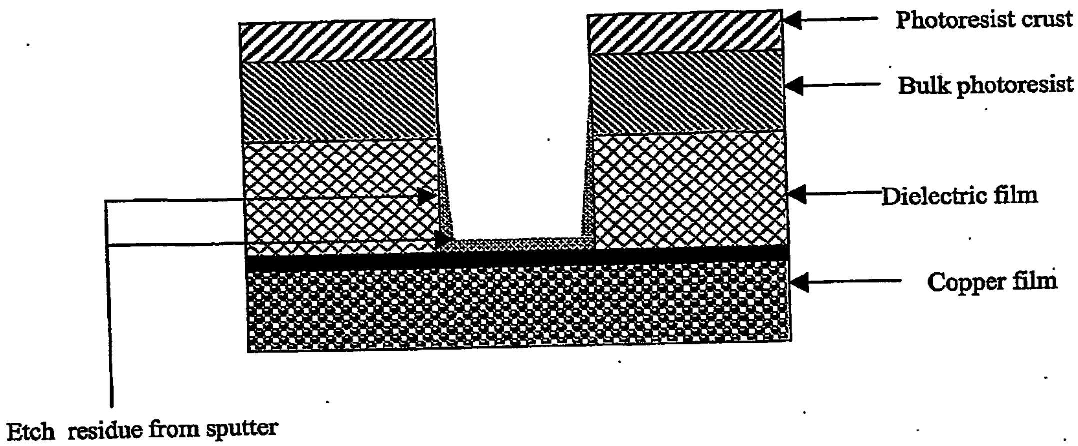

Fig. 1. Drawing of a post-etch structure showing remaining crusted resist and polymeric etch residues on the sidewall of the feature.